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Describes procedures for measuring the sound levels of developmental and production materiel as a means of evaluating personnel safety, recognition and community annoyance. It covers tests for steady-state noise from military vehicles and general equipment, and impulse noise from military weapon systems.

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US ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

*Test Operations Procedure 01-2-608A 1 August 2011
DTIC AD No.

SOUND LEVEL MEASUREMENTS

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*This TOP supersedes TOP 01-2-608, Sound Level Measurements, 17 July 1981.

1. SCOPE.

This Test Operations Procedure (TOP) describes procedures for measuring the sound levels transmitted through air of developmental and production materiel as a means of evaluating personnel safety, speech intelligibility, security from acoustic detection and recognition, and community annoyance. It covers tests for steady-state noise from military vehicles and general equipment, and impulse noise from weapon systems and explosive-ordnance materiel. For materiel that produces sound-pressure levels 171 decibels (dB) (6.89 kilopascal (kPa) or 1.0 pounds per square inch (psi)) and above, the procedures and instrumentation described in International Test Operations Procedure (ITOP) 04-2-822[1], for measuring blast overpressure, apply. This TOP does not include procedures for measuring the noise from aircraft.

1.1 Steady-State Noise.

Per Military Handbook (MIL-HDBK)-1908B[2], steady-state noise is defined as a periodic or random variation in atmospheric pressure at audible frequencies. It may be continuous, intermittent, or fluctuating, with the sound-pressure level varying over a wide range, provided such variations have a duration exceeding one second.

1.2 Impulse Noise.

For test purposes, impulse noise is defined as a short burst of acoustic energy consisting of either a single impulse or a series of impulses. The pressure-time history of a single impulse includes a rapid rise to a peak pressure, followed by a somewhat slower decay of the pressure envelope to ambient pressure, both occurring within 1 second. A series of impulses may last longer than 1 second. The following data are required for the evaluation of impulse noises:

a. Peak pressure level in dB or psi.

b. A-Duration (Primary Pressure-Wave Duration). The time required for the pressure to rise to its principal positive peak and return momentarily to ambient pressure.

c. B-Duration (Pressure-Envelope Duration). The duration of the primary portion of an impulse noise, plus the duration of significant subsequent fluctuations. These durations are considered to be the time interval during which the envelope of pressure fluctuations (positive and negative) is within 20 dB of the peak-pressure level. Significant subsequent pressure fluctuations are those whose summed duration is greater than 10 percent of the duration of the primary portion. The primary portion of an impulse noise is that period of time which is followed by a level which remains 20 dB below the peak-pressure level for a significant duration. A more detailed explanation is provided in Military Standard (MIL-STD)-1474D[3], Requirement 4, paragraph 6.5.

*Superscript numbers correspond to Appendix D, References.

d. For systems that produce repetitive impulses, determine the number of impulses produced within the first 200 millisecond (ms). This number of impulses is multiplied by the average B-duration of single impulses to determine an effective B-duration, which is used to establish the maximum allowable peak-pressure level for the repetitive system.

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

2.1.1 Steady-State Noise.

2.1.1.1 Stationary Operation Tests.

a. Equipment shall be tested in its exact operating location if the location is known and such testing is feasible. When this is not possible, the test site shall be a uniformly flat grass surface, free of ice, snow, or vegetation over 15 cm (6 in.) tall; it shall be free of reflecting surfaces such as objects, buildings, trees, or hillsides within 30 meters (100 ft) of the test item and sound measuring equipment.

b. For test items permanently mounted, test the item on-site, and state the conditions in the test report.

c. For a test item that produces sound levels within l0 dB of the average, ambient, sound-pressure level of the test site, use an anechoic chamber that has an ambient, sound-pressure level at least 10 dB below that of the item being tested, and always at least 10 dB below the criteria. ITOP 04-2-822 provides the formulas for converting dB, psi, and kPa, if converting is necessary. Where applicable, use a windscreen when testing in wind velocities of 10 kilometers per hour (km/hr) (6 miles per hour (mph)) or more, but measurements shall not be made at velocities of 20 km/hr (12 mph) or more. An exception to this requirement is when conducting aural nondetectability measurements; the use of conventional background-noise corrections is permitted in accordance with American National Standards Institute (ANSI) S1.13[4].

2.1.1.2 Interior-Noise Tests.

These tests require a smooth, straight paved road, that is level (<1 percent grade) and free of all loose gravel or other foreign matter; long enough to allow the vehicle to accelerate by 8- or 16-km/hr (5- or 10-mph) increments to the maximum speed tolerated by the vehicle, operator, or track in all forward gears and to maintain that speed for at least 30 seconds; and free of all sound-reflecting surfaces for a distance of 30 meters (100 ft) on each side. For tracked vehicles without rubber pads, a similar course of compact earth having a cone index in the range of 100 to 150 is required unless otherwise specified. Measurements shall not be made when the road surface is wet, covered with snow or ice, or during precipitation, unless specified by the procuring activity.

2.1.1.3 Exterior-Noise Tests of Moving Equipment.

a. Vehicle Course.

These tests require a smooth, straight, paved road that is level (<1 percent grade) and free of all loose gravel or other foreign matter; at least 60 meters (200 ft) in length; and free of all sound-reflecting surfaces for 30 meters on each side. For tracked vehicles without rubber pads, a similar course of compact earth having a cone index in the range of 100 to 150 is required unless otherwise specified. Measurements are not made when either the road surface or measurement surface is wet, covered with snow or ice, or during precipitation, unless specified by the procuring activity.

b. Watercraft Course.

A body of water of sufficient area and smoothness to permit normal operation and maneuvering of the craft at maximum operational speeds is required. For pass-by tests, the area must be free of large obstructions (large piers, breakers, etc.) for a minimum of 30 meters from the course the craft is to follow. Place three marker buoys in a straight line 15 meters (50 ft) apart to mark the course.

2.1.1.4 Aural-Nondetectability Test.

For these tests, select an open area of uniform grade; with a uniform, flat, grass surface free of vegetation over 15 cm (6 in.) tall, snow, or other sound-absorbing materials; and free of sound-reflecting surfaces located within 30 meters of either the test item or sound measuring equipment. For stationary tests of extremely low-noise-level items, use an anechoic chamber.

2.1.1.5 Speech-Intelligibility Test.

When possible, use the natural environment of the test item (i.e., its normal position of intended use) when testing against speech-intelligibility criteria. One of the following will usually be required:

a. An Open-Field Facility is considered an open field, free of all large buildings or high hills that would reflect or block sound energy, and having an ambient-sound level equal to or below 50 dBA.

b. A Closed-Room Facility is considered a room or chamber similar in acoustic characteristics to the location in which the test item is used. Vehicle communication sets are tested in the vehicle(s) in which they are intended to be used. The ambient noise will vary with respect to the facility, and if no facility is specified, use 50 dBA as the maximum allowable ambient-pressure level.

2.1.1.6 Air-Conditioner Tests.

These tests require a chamber with an acoustical tile ceiling and a movable wall to provide a room of the size for which the air conditioner was designed. The room should be empty except for sound-measuring instrumentation and electrical heater banks.

2.1.2 Impulse Noise.

a. Select a range to suit the type of weapon and firing, or detonation requirements.

b. Reflecting Surfaces. Where practical, measurements shall be made with no reflecting surfaces, including personnel, within 10 meter (33 ft) of both the test item and the transducers. For weapons that must be supported, a stand shall be used having minimal reflecting or obstructing surfaces. An unimpeded reflecting path from the noise source(s) to the ground and back to the transducers shall be provided.

2.2 Instrumentation.

2.2.1 Steady-State Noise.

a. Microphones. Pressure microphones shielded against wind effects, having an essentially flat response at grazing incidence (90 º) should be used. Free field microphones having an essentially flat response at normal incidence (0 º) can be used with the addition of a random-incidence corrector. They must have a flat frequency response between 20 hertz (Hz) and 18 kilohertz (kHz).

b. Sound-level meters. Must conform to the requirements for Type 1 as specified by ANSI S1.4[5].

c. Octave band filter sets. Must conform to the requirements for Order 3, Type 3-D, extended range, as specified by ANSI S1.11[6].

d. Other noise recording equipment or combinations of instrumentation shall conform to ANSI S1.4.

e. Frequency analyzer providing dBA, and octave-band levels.

2.2.2 Impulse Noise.

2.2.2.1 Transducers.

a. Undamped resonance. Undamped resonance shall be not less than 100 kHz.

b. Time constants. For other than direct current (DC) response, time constants shall be not less than 200 ms.

c. Non-linearity. Non-linearity shall be not greater than 3 percent of full scale output.

d. Sensor surfaces and holders. Diameters of sensor surfaces shall be not more than 6.4 mm. Transducer holders should be small and minimize flow interference over the sensor surface.

e. Rise-time. Rise time capability shall be less than 1/20 of the measured A duration of the impulse and should be not more than 20 microseconds. Cables that cause an increase in measured rise time shall not be used.

f. Acceleration sensitivity. Acceleration sensitivity shall be less than 0.014 kPa/g in the axial direction, and less than 0.069 kPa/g in the transverse direction.

2.2.2.2 Transducer Applications.

a. For measurements above 40 kPa (186 dB), pointed or disc-shaped piezoelectric or piezoresistive probes with good aerodynamic characteristics shall be used.

b. For measurements below 40 kPa (186 dB), piezoelectric or piezoresistive probes having a blunt cylinder shape may be used.

c. For measurements above 7 kPa (171 dB), condenser microphones shall not be used.

2.2.2.3 Recording System.

Record impulse noises using a digital recorder. Sampling rate shall be a minimum of 200,000 samples/second. The analog signal shall be filtered, using a Bessel type, with 40-kHz cutoff frequency. The roll-off rate shall be not less than 36 dB/octave. The complete data acquisition system shall provide a minimum of 35 dB signal-to-noise ratio.

2.2.2.4 Alternate-Noise Instrumentation. Any sound-recording devices, components, or combinations of instrumentation used as part of or in lieu of the above items shall conform to ANSI S6.1[7] and applicable provisions of ANSI S1.4.

3. REQUIRED TEST CONDITIONS.

3.1 Steady-State Noise.

3.1.1 Safety.

a. All personnel exposed to hazardous noise or blast levels must wear hearing protection as required by Army Regulation (AR) 40-5[8], Chapter 4, Section IV or equivalent as prescribed by the pertinent Standing Operating Procedure (SOP). Personnel who will be occupationally exposed to steady-state noise levels of 85 dBA or greater, or peak-pressure levels of impulse

noise above 140 dB, shall also been entered in a hearing-conservation program as outlined in Technical Bulletin Medical (TB MED) 501[9].

b. During tests, neither the operator nor crew members shall occupy the location(s) where the noise is being measured, unless they are essential to the operation of the test item and the hearing protection provided is capable of reducing the expected noise to nonhazardous levels. Department of the Army Pamphlet (DA PAM) 40-501[10], Chapter 6, provides additional guidance on hearing protectors.

3.1.2 Vehicles.

a. Equip all vehicles with a calibrated tachometer.

b. When possible, select new vehicles for the test (vehicles that have completed the prescribed break-in time). Inspect for normal operation in accordance with the appropriate specification and to ensure that all auxiliary equipment that would be in continuous use when the vehicle is in motion, is installed and operating normally.

c. Load all load-carrying vehicles (trucks, trailers, forklifts, etc.) with two-thirds of their usual rated payloads.

d. Install all panels, canvas, louvers, and equipment used on the vehicle.

e. Check and adjust tire pressure or track tension to that prescribed for the load.

3.1.3 Stationary Equipment.

a. All safety equipment such as guards, mufflers, and warning devices shall be installed.

b. All noise-producing, auxiliary equipment, normally used with the test item, shall be installed.

3.1.4 Environment.

a. Ambient noise level for steady-state noise tests shall be at least 10 dB below the noise being measured and shall always be at least 10 dB below the criteria. Ambient noise level for impulse-noise tests shall be at least 40 dB below the peak pressure level being measured for acceptance, and at least 20 dB below the peak pressure level for noise contours.

b. Tests shall not be conducted when wind exceeds 20 km/hr (12 mph), or during precipitation. Microphones shall be shielded from wind effects under all conditions.

c. When the ambient temperature changes more than 3 ºC (5 ºF) during the conduct of the test, an instrumentation-alignment check shall be made after each series of measurements.

3.2 Impulse Noise.

a. Weather Conditions. The effect of weather conditions (e.g., temperature, humidity, and barometric pressure) on the performance of all instruments should be considered. Instrumentation can be affected by low temperatures and caution should be exercised. Measurements should normally be made at wind speeds below 20 km/hr (12 mph). However, this guideline may be eased when measuring high sound pressure levels.

b. Background Noise. Background noise, including wind noise, shall be at least 40 dB below the peak pressure level being measured for acceptance and at least 20 dB below the peak pressure level for noise contours.

4. TEST PROCEDURES.

4.1 Steady-State Noise.

4.1.1 Noise Tests of Stationary Equipment.

a. Generators, Pumps, Heaters, and Other Power Equipment.

(1) Place microphones at the approximate centers of the probable head positions of all operating and maintenance personnel. Maintenance personnel noise measurements shall be taken with acoustic enclosure panels removed and access panels open with the microphone placed at the probable head position.

(2) Operate equipment in a manner most descriptive of its normal operating condition and record dBA and octave-band pressure levels at all microphone locations. When the noise generated by operating conditions varies due to load, speed, or other reasons, conduct the test under that condition which produces the highest noise level.

(3) When the operating noise level is 85 dBA or greater, determine the distances and directions from the noise source at which the noise level is equal to 85 dBA. The 85 dBA contour shall be determined from measurements made at positions around the noise source at angular increments not greater than 45 º, and at the noisiest angle. Make as many noise measurements as necessary to accurately plot an 85 dBA contour curve.

b. Vehicles.

(1) Microphone Locations.

(a) Place microphones 150 mm (6 in.) to the right of the driver's right ear and at the center of the probable head position of all other normally occupied positions during field use. For vehicles expected to carry more than five persons, place microphones at five representative positions. Where the operator, crew, or passenger station(s) is not clearly defined, or where

unattended use of equipment is intended (e.g., some mobile electric power, pumps, etc.), the noise measurement position(s) shall be designated by the procuring activity.

(b) If an 85-dBA contour curve around the exterior of the vehicle is required, place microphones at angular increments not greater than 45 º around the vehicle, and determine the distance at each radial at which the noise level is equal to 85 dBA.

(2) Operate the vehicle at idle and at two-thirds of the maximum-rated engine revolutions per minute (rpm). Operate vehicles having torque converters at their maximum, attainable, governed speed at torque-converter stall conditions. Observe appropriate limitations on idle and stall operations to prevent overheating or damage.

(3) Record dBA and octave-band pressure levels at all interior microphone locations with windows open and again with windows closed.

c. Air Conditioners. These tests require a chamber with an acoustical tile ceiling and a movable wall to provide a room the size for which the air conditioner was designed. The room should be empty except for sound measuring instrumentation and electrical heater banks.

d. Mount the air conditioner so that the evaporator grille is 1.22 meters (48 in.) from the floor and centered in one end of the wall of the air conditioner test facility, with the evaporator side protruding at least 102 mm (4 in.) inside the wall (Figure 1).

e. Record the sound-pressure level at three locations inside and three locations outside the test chamber as follows:

(1) Inside. On a centerline perpendicular to the evaporator grille, 30 º to the left, and 30 º to the right of that center line. All positions are 1.22 meters (48 in.) from the center of the grille and 1.22 meters above the floor.

(2) Outside. On a centerline perpendicular to the condenser grille, 45 º to the left, and 45 º to the right of that center line. All positions are 1.22 meters from the center of the grille and at a height on line with the center of the grille.

(3) Operate the air conditioner at its maximum cooling capacity (coldest temperature setting and maximum blower speed) and record dBA and octave-band pressure levels at each microphone location.

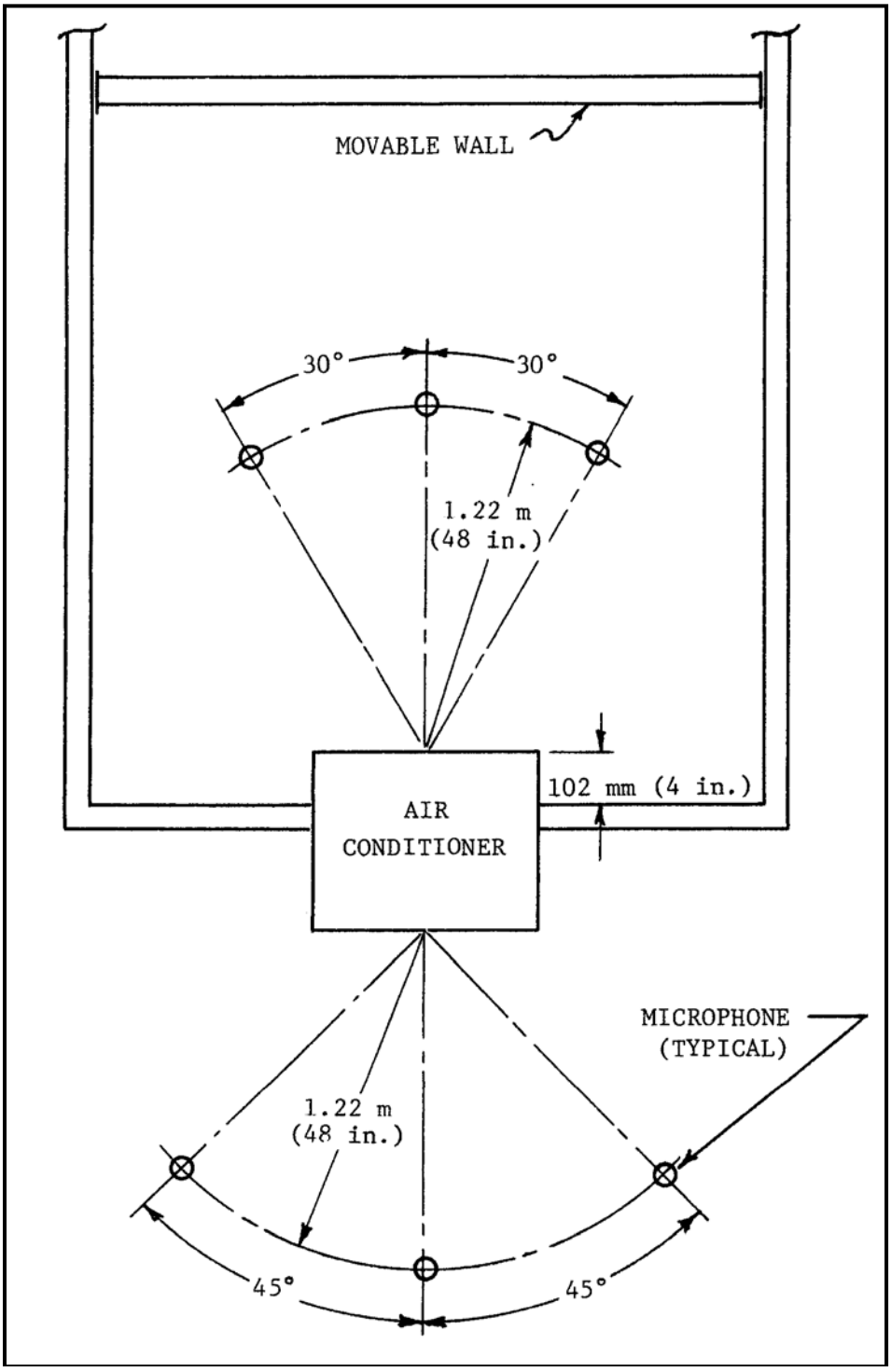

Figure 1. Air conditioner test setup.

4.1.2 Interior-Noise Tests of Moving Equipment.

a. Wheeled Vehicles.

(1) Microphone Locations. Place microphones 150 mm (6 in.) to the right of the driver's right ear and at the center of the probable head position of the assistant driver, and at all positions normally occupied during field use. For vehicles expected to carry more than five persons, place microphones at five representative positions. Where the operator, crew, or passenger station(s) is not clearly defined, or where unattended use of equipment is intended (e.g., some mobile electric power, pumps, etc.), the noise measurement position(s) shall be designated by the procuring activity.

(2) Vehicle Speed. Operate the vehicle in 8- to 16-km/hr (5- to 10-mph) increments to the maximum speed tolerated by the vehicle, operator, or track in the highest gear, over a paved test course, as in paragraph 2.1.1.3.a). Additional measurements may be made in all other gears at two-thirds of maximum or posted vehicle speed for that gear.

(3) Auxiliary Equipment. All auxiliary equipment that adds to the overall noise level (e.g., heaters, blowers, air conditioners) shall be operated at their highest setting. Where both heaters and air conditioners are present, the one producing the higher sound level shall be operated.

(4) Vehicle Payloads. All load-carrying equipment shall be operated with two-thirds of maximum payload or as specified by the procuring activity. Vehicles (including tractor/trailer combinations) shall be operated at two-thirds of the off-highway payload. Auxiliary trailed equipment shall not be towed during the test. Vehicles shall also be tested at the maximum payload including towed trailers at maximum payload where applicable to the vehicle design.

(5) Equipment Openings. All windows, hatches, and vents shall be in the normal operation position as defined by the procuring activity. If possible to operate with these either in the open or closed positions, both configurations shall be tested.

(6) Record dBA, and octave-band pressure levels at each microphone location.

b. Tracked Vehicles. Conduct the test as in paragraph 4.1.2.a(2) except that when the tracks are without rubber pads, operate the vehicles on compact earth, as in paragraph 2.1.1.3.a.

c. Small Watercraft (applies to craft having fixed positions for crew and passengers, and sound generated only by the propulsion unit).

(1) Place a microphone at the approximate ear positions of the operator, each crew member, and each passenger.

(2) Operate the craft in calm water, 150-mm (6-in.) waves or less, at five evenly spaced speed increments from slow to maximum.

(3) Record dBA, and an octave-band analysis at each microphone location for each speed.

d. Large Watercraft (applies to vessels with multiple sources of noise).

(1) Operate the vessel in waters not to exceed moderate seas, l-meter (3-ft) waves or less, at varying speeds up to and including top speed (flank).

(2) Conduct a noise survey of the pilothouse, crew compartment, engine rooms, and work areas under all conditions of vessel operation, using a sound-level meter. With all special equipment normally used in that compartment operating, determine positions of maximum noise.

(3) Place a microphone in the area of maximum noise of each compartment and record the dBA and octave-band analysis for the condition-of-vessel operation that produces the most noise.

(4) When cargo-handling, vehicle-movement, or pumping operations are part of the normal working operation of the vessel, conduct separate test of each of these operations while the vessel is moored.

4.1.3 Exterior-Noise Tests of Moving Equipment (Drive-By).

a. Motor Vehicles (Society of Automotive Engineers (SAE) Procedure J-366[11]).

(1) Test Site Setup. The microphone shall be located 15.2 meters (50 ft) from the centerline of the vehicle travel, and 1.2 meters (4 ft) above the ground plane. The microphone point is defined as the point of intersection of the vehicle path, and the normal to the vehicle path drawn from the microphone (Figure 2).

(2) The microphone shall be oriented with respect to the source so that the sound strikes the diaphragm at an angle at which the microphone was designed to have the flattest frequency response over the frequency range 100 Hz to 10 kHz.

(3) An acceleration point shall be established on the vehicle path 15.2 meters (50 ft) before the microphone point.

(4) An end point shall be established on the vehicle path 30.4 meters (100 ft) from the acceleration point and 15.2 meters (50 ft) from the microphone point.

(5) The end zone is the last 12.2 meters (40 ft) of vehicle path prior to the end point.

(6) The measurement area shall be the triangular area formed by the acceleration point, the end point, and the microphone location.

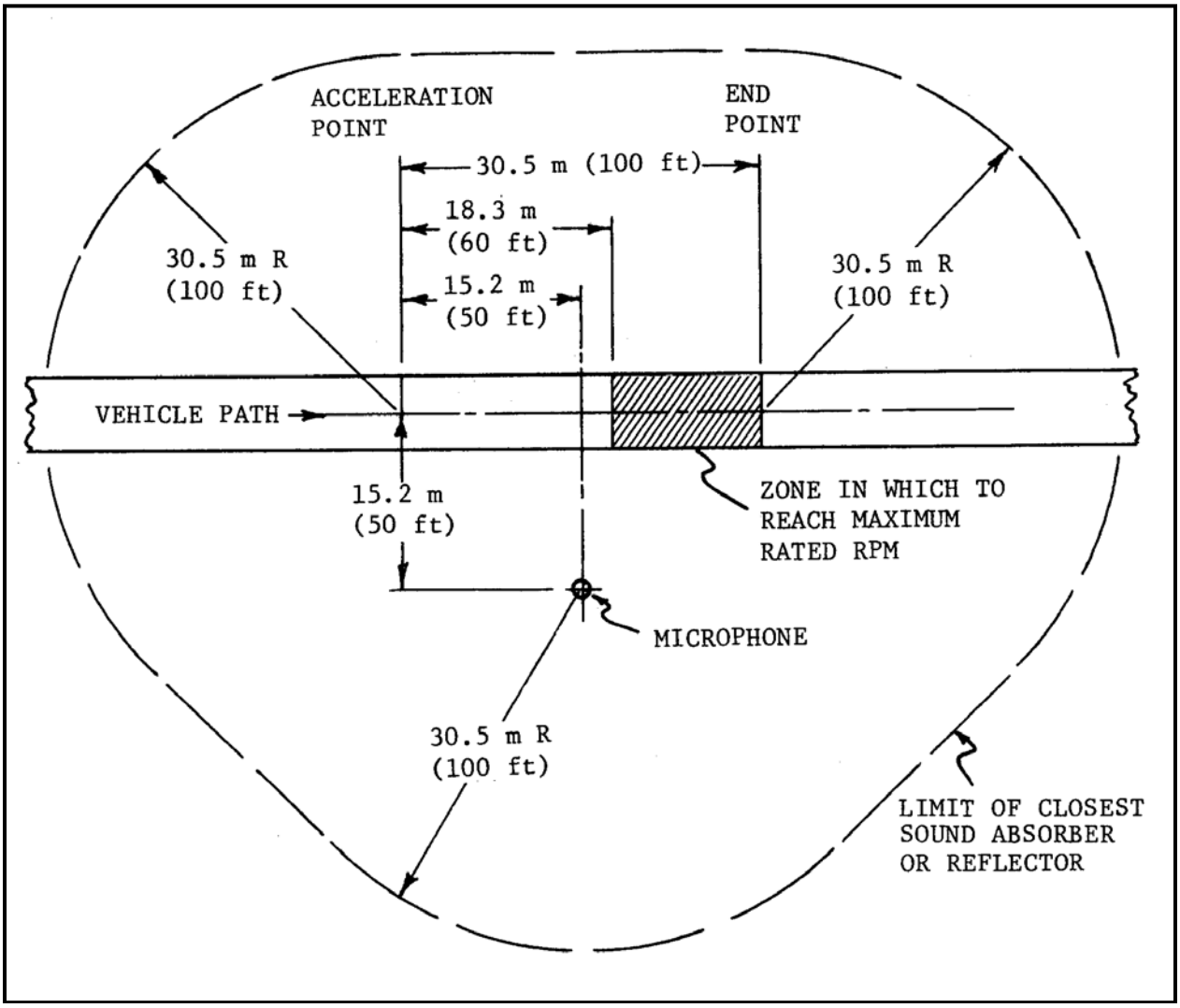

Figure 2. Motor vehicle drive-by noise test setup (SAE J366).

(7) Acceleration Test. Select the highest rear axle and/or transmission gear (highest gear is used in the usual sense; it is synonymous to the lowest numerical ratio) and an initial vehicle speed such that a wide-open throttle of the vehicle will accelerate from the acceleration point:

(a) Starting at no more than two-thirds (67 percent) of maximum rated engine speed.

(b) Reaching maximum test speed within the end zone.

(c) Without exceeding 55 km/hr (35 mph) before reaching the end point.

(8) Deceleration Test. For the deceleration test, approach the microphone point at maximum test speed in the gear selected for the acceleration test. At the microphone point, close the throttle and allow the vehicle to decelerate to one-half of maximum test speed. If the vehicle is equipped with an exhaust brake, this deceleration test is to be repeated with the brake full on immediately following closing of the throttle.

(9) Data. Set the sound-level meter for fast response on the A-weighted network. Observe the sound-level meter during the period that the vehicle is accelerating and record maximum dBA values as the vehicle is driven past the microphone. The applicable reading is the highest sound level obtained for the run (ignoring peaks caused by extraneous ambient noise).

(10) Make at least three measurements on each side of the vehicle unless it becomes obvious after the first run that one side is definitely higher in sound level. Report the sound level for the side of the vehicle with the highest readings.

(11) Report the sound level as the average of the two highest readings that are within 2 dB of each other.

b. Powered Mobile-Construction Equipment (SAE Procedure J88[12]). Conduct this test using the same procedure as in paragraph 4.1.3.a except:

(1) Machines shall be operated at a constant speed in a forward intermediate gear ratio at no-load at a location as specified in Figure 3. The power source(s) shall be operated at maximum governed speed (high idle). Intermediate is intended to mean second gear ratio for machinery with three or four gear ratios, third gear ratio for machinery with five or six gear ratios, fourth gear ratio for machinery with seven or eight ratios, etc. If there is a problem with the transmission shifting up or down in this phase of the test, one gear lower or higher may be used to eliminate the problem. Machines with hydrostatic, electric drive, or other type drives shall be operated at approximately one-half its maximum ground speed with the governor control set in maximum (high idle) position at no-load. If this operating condition cannot be attained because of the interaction of the power source(s) and drive controls, then the ground speed may be increased or decreased so as to still permit the power source(s) governor control(s) to be set in the maximum (high idle) position.

(2) Machines that have major noise-generating components which are normally in use at this ground speed shall have these major components in operation during this test. For self-propelled street sweepers, these components include water systems, brooms, and blower or conveying systems.

(3) Machines that have a major attachment that is normally used for the main operating function shall be equipped with this attachment.

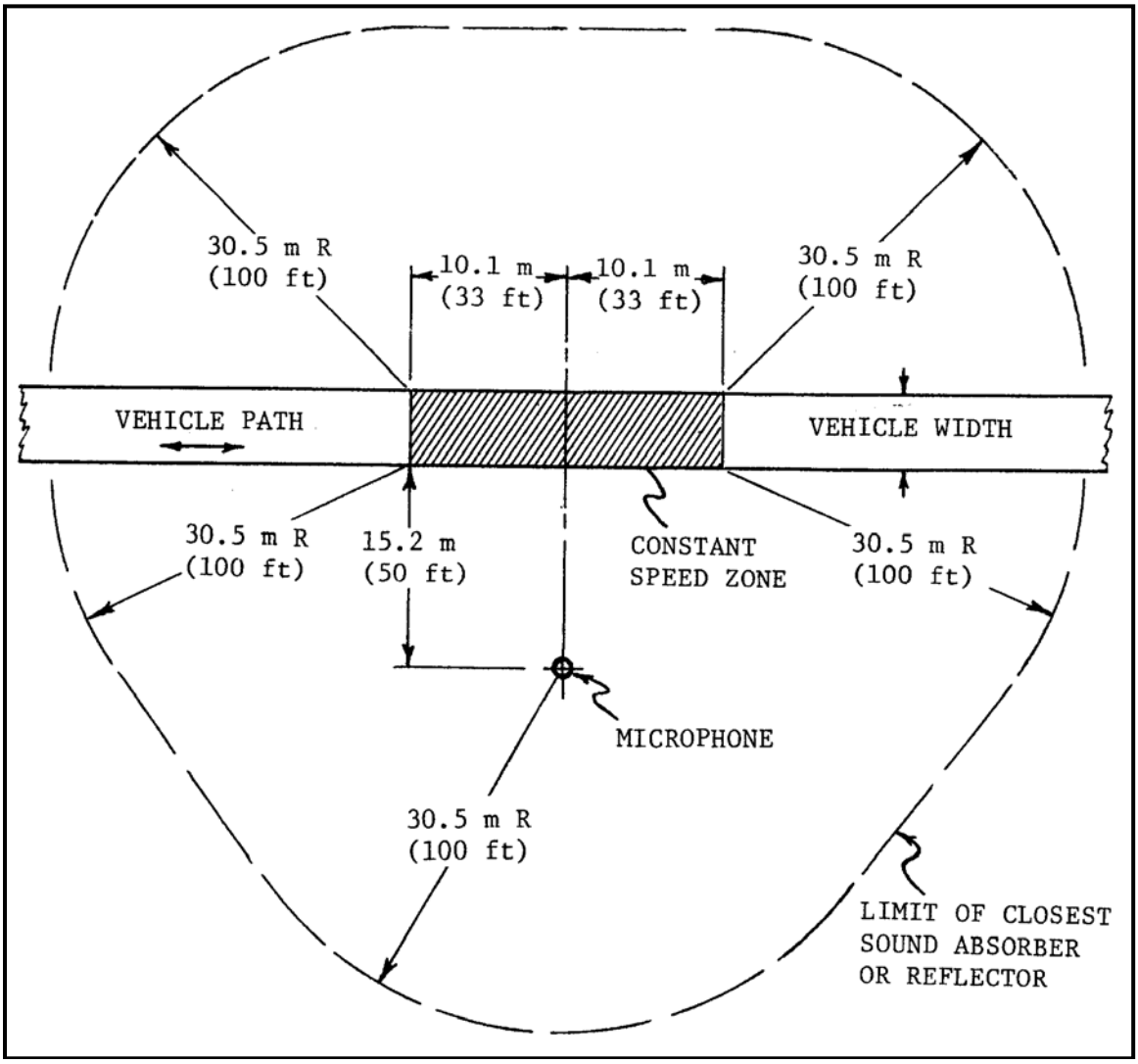

Figure 3. Powered mobile-construction-equipment drive-by noise test (SAE J88).

c. Watercraft (SAE Procedure J34[13]).

(1) Place a microphone 25 meters (82 ft) from the line described by three course markers (paragraph 2.1.1.3.b) on a dock, a floating platform, or another boat. Position the microphone so that it is perpendicular to the line of markers, opposite the center marker at 1.2 to 1.5 meters (4 to 5 ft) above the water surface, and not closer than 0.6 meter (2 ft) to the surface of the dock or platform on which the microphone stands.

(2) Set the sound-level meter for fast response on the A weighting network.

(3) Operate the craft so that it passes within approximately 0.5 to 1 meter (1.6 to 3.2 ft) of the far side of all three markers with the engine operating at the midpoint of the full-throttle rpm range recommended by the manufacturer.

(4) Observe the sound-level meter while the craft is passing the markers and record the maximum dBA reading.

(5) Make at least three measurements for each side of the craft.

(6) Report the sound level for each side of the craft. The sound level for each side of the boat shall be the average of the first two readings for each side which are within 1 dB of each other.

4.1.4 Aural-Nondetectability Tests.

a. Equipment having an aural nondetectability requirement shall not exceed the limits of Tables 1 or 2, as specified by the procuring activity. Two category limits are available. The selection of the category is based upon the anticipated use of the equipment and the criticality of the aural nondetectability.

(1) Category Level I (Table 1) nondetectability limit assumes that the listener is in a quiet rural area with the closest heavily used highway and community noise sources further then 4 km (2.5 mi) away.

(2) Category Level II (Table 2) nondetectability limit assumes that the listener is in a quietest background noise level with the closest heavily used highway and community noise sources further then 10 km (6.2 mi) away.

(3) Select from Table 1 or 2 a measurement distance that corresponds to the nondetectability range desired or requested by the requirements document. Unless otherwise specified, the octave-band-pressure levels measured at the measurement distances must not exceed those values listed in the table for any band at any azimuth around the equipment if nondetectablity is to be achieved at the corresponding distances. If the ambient noise is less than 10 dB below the level of the test item, the use of conventional, background-noise corrections is permissible (ANSI S1.13). If the test item is small and meets the safety requirements, the test may be conducted in an anechoic chamber. When measuring the noise of a large item at close distances, the measurement distance must be more than four times the major dimension of the item.

b. Test Site. Equipment shall be tested in its exact operating location if the location is known and such testing is feasible. When this is not possible, the test site shall be a uniform flat grass surface, free of ice, snow, or vegetation over 15 cm (6 in.) tall; and it shall be free of reflecting surfaces such as buildings, trees, or hillsides within 30 meters (100 ft). An anechoic or hemi-anechoic chamber may be substituted for outdoor measurements.

TABLE 1. LEVEL I AURAL NONDETECTABILITY LIMITS (dB)

1/3 Octave Band Frequency (Hz)	Nondetectability Distance (m)																
	10	20	30	100	200	300	400	500	750	1000	1250	1500	2000	3000	4000	5000	6000
50	53	59	62	61	68	71	74	66	70	73	75	76	79	84	87	90	92
63	50	52	56	59	65	69	71	64	68	71	73	75	78	83	87	91	94
80	49	45	58	60	66	69	72	65	69	72	75	77	81	87	93	97	101
100	46	41	56	59	65	69	72	65	70	73	77	79	84	92	99	104	107
125	41	35	51	58	64	69	72	65	71	76	79	83	89	98	102	105	106
160	39	33	48	55	63	68	72	66	73	79	84	88	93	97	99	101	102
200	42	37	51	52	61	67	72	68	78	82	85	87	89	92	94	96	97
250	44	40	53	50	61	69	76	71	76	79	80	81	83	86	89	91	93
315	46	41	54	50	63	71	75	68	71	73	74	75	77	81	83	86	88
400	43	37	50	51	62	66	68	62	64	66	67	69	71	75	78	81	84
500	42	40	54	54	61	64	66	55	58	60	61	63	65	70	73	77	80
630	37	38	54	55	63	67	68	53	56	58	60	61	64	69	74	78	82
800	31	31	47	54	63	66	68	54	57	59	61	63	66	72	77	82	87
1000	29	27	42	50	59	63	65	54	57	60	62	64	68	74	80	86	91
1250	31	24	39	42	52	57	59	54	57	60	62	65	69	76	83	90	96
1600	31	23	35	36	46	51	54	52	56	59	62	64	69	78	87	95	NA
2000	25	23	32	36	47	52	55	50	54	58	62	65	71	82	92	97	NA
2500	26	28	31	28	39	44	48	46	52	56	60	64	72	86	NA	NA	NA
3150	21	19	34	29	40	46	50	40	47	53	59	64	74	94	NA	NA	NA
4000	21	18	34	25	37	44	49	39	48	56	64	71	86	NA	NA	NA	NA
5000	18	21	25	23	35	43	50	48	60	71	82	93	NA	NA	NA	NA	NA
6300	20	25	30	27	40	50	58	56	73	89	NA	NA	NA	NA	NA	NA	NA
8000	30	35	39	40	54	67	78	79	NA	NA	NA	NA	NA	NA	NA	NA	NA
10000	31	37	42	47	64	81	96	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Measurement Distance (m)	2	2	2	10	10	10	10	30	30	30	30	30	30	30	30	30	30

TABLE 2. LEVEL II AURAL NONDETECTABILITY LIMITS (dB)

1/3 Octave Band Frequency (Hz)	Nondetectability Distance (m)																
	10	20	30	100	200	300	400	500	750	1000	1250	1500	2000	3000	4000	5000	6000
50	53	59	62	61	68	71	74	66	70	73	75	76	79	84	87	90	92
63	46	52	56	55	61	65	68	60	64	67	69	71	74	79	83	87	90
80	39	45	49	50	56	60	62	55	59	62	65	67	71	78	83	87	91
100	35	41	44	48	54	58	61	54	58	62	65	68	73	81	87	93	95
125	29	35	38	45	52	56	60	53	59	63	67	71	77	86	90	92	94
160	27	33	37	44	51	56	60	55	62	68	73	77	81	85	90	90	91
200	32	37	41	42	51	57	62	58	77	72	75	76	79	82	84	86	87
250	35	40	44	41	52	60	66	62	67	69	71	72	74	77	80	82	83
315	37	41	46	42	55	63	66	60	63	64	66	67	69	72	75	78	80
400	34	37	41	42	53	57	59	53	55	57	59	60	62	66	69	72	75
500	33	40	45	45	52	55	57	46	49	50	52	54	56	60	64	68	71
630	27	38	44	45	53	57	58	43	46	48	50	51	44	59	64	68	72
800	21	31	37	44	53	56	58	44	47	49	51	53	56	62	67	72	77
1000	19	27	32	40	49	53	55	44	47	50	52	54	58	64	70	76	81
1250	21	24	29	32	42	47	49	44	47	50	52	55	59	66	73	80	86
1600	22	23	26	27	37	42	45	43	47	50	53	55	60	69	78	86	94
2000	16	23	23	27	38	43	46	41	45	49	53	56	62	73	83	94	NA
2500	18	28	23	20	31	36	40	38	44	48	52	56	64	78	92	NA	NA
3150	13	19	26	21	32	38	42	32	39	45	51	56	66	86	NA	NA	NA
4000	14	18	27	18	30	37	42	32	41	49	57	64	79	NA	NA	NA	NA
5000	13	21	20	18	30	38	44	43	55	66	77	87	NA	NA	NA	NA	NA
6300	20	25	30	27	40	50	58	56	73	89	NA	NA	NA	NA	NA	NA	NA
8000	30	35	39	40	54	67	78	79	NA	NA	NA	NA	NA	NA	NA	NA	NA
10000	31	37	42	47	64	81	96	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Measurement Distance (m)	2	2	2	10	10	10	10	30	30	30	30	30	30	30	30	30	30

c. Microphone Location. The microphone shall be positioned 1.2 meters (48 in.) above the ground, on 30 º radials around the test item at the indicated measurement distance. The noise of an item should, whenever possible, be measured at a distance of at least four times the major dimension of the source. Measurements made at this distance follow the inverse square law (6-dB decrease for each doubling of distance) with the resulting measurements being appropriate for predicting nondetectability. Record the linear (nonweighted) sound pressure levels in each octave band at each location.

d. Vehicle Stationary - Silent Watch.

(1) While the item is completely silent, record the ambient sound-pressure level in each octave band.

(2) Place the vehicle in a silent watch condition (i.e., radio, rangefinder, and other electronic equipment turned on and all other noise-producing devices or equipment turned off). Record the sound-pressure level in each octave band.

e. Vehicle Stationary - Combat Readiness. Repeat the procedure described in paragraph 4.1.4.d with the vehicle engine at idle and all heaters, weapon systems, and electronic instruments operating. Record the sound-pressure level in each octave band.

f. Equipment at Idle (Standby Condition).

(1) Place the microphone at the selected distance from the test item. While the item is completely silent, record the ambient sound-pressure level in each octave band.

(2) Turn the equipment to its lowest operable condition (idle) and again record the sound-pressure level in each octave band.

g. Equipment at Maximum Working Condition. Use the procedure described in paragraph 4.1.4.f, except operate the test equipment at its normal maximum-load condition. If, by reducing or increasing the speed or working condition of the test item, the noise level increases, conduct the test at that speed or condition that produces higher noise levels unless detrimental to the test item to do so.

4.1.5 Speech-lntelligibility Tests.

For equipment that requires effective oral communication among crew or passengers for field employment, a speech-intelligibility test may be necessary. When required, conduct the speech-intelligibility test as described in TOP 01-2-610[14].

4.1.6 Typical-Duty-Cycle Tests.

If a typical duty cycle testing is specified by the procuring activity, a time-weighted average level (Lavg) shall be determined using an integrating sound level meter or other recording instruments that measures (Lavg) as defined in MIL-HDBK-1908B (using the time-sound level

exchange rate appropriate for the service involved). Minimum sampling time shall be 10 minutes and should consist of integral multiples of duty cycles. When the Lavg does not change by more than 2.0 dBA from sample to sample, two samples shall be adequate. If additional data samples are needed, data samples shall be taken until the number of samples made is at least as large as the dBA range of results for the data set (e.g., a range of 5 dBA between data samples would require at least 5 samples). The equipment shall be operated at a test site typical of the environment in which the equipment is to be used, as specified by the procuring activity. The composite Lavg from all samples shall represent the duty-cycle noise. Excluding individual samples from the composite average is permissible for operator error in mechanical performance during the sampling.

4.2 Impulse Noise.

4.2.1 Personnel Occupied Areas.

a. Weapon Position.

Weapons shall be tested in all positions and in the system locations from which they are normally fired. Standing position for shoulder-fired and hand-held weapons is defined as being mounted with the barrel or tube centerline 1.60 meters (5.2 ft) above and parallel to the ground. For vehicle mounted weapons, mount the weapon in or on the vehicle as it would be under normal combat or training conditions. Position the vehicle to create the most severe noise conditions with respect to the crew members (e.g., gun firing directly over the hatch of a crew member) when firing the weapon down range.

b. Transducer Locations.

For shoulder-fired and hand-held weapons operated remotely, transducers shall be located at the center of each operator or crew member's probable head location. For other weapons the transducer shall be positioned 1.60 meters (5.2 ft) above the ground surface; for sitting locations it shall be 80 cm (31 in.) above the seat. When the operator must be present, the measurement shall be made 15 cm (6 in.) from the ear closest to the main noise source (i.e., muzzle or breech, as the case may be) on a line between the operator's ear and the noise source. For vehicle mounted weapons, mount a transducer at the center of the probable head position of each crew member while in a seated position. With the vehicle hatches closed, fire the weapon and record sound-pressure level, A-duration, and B-duration at each crew position. Repeat the above test with the hatches open.

c. Measure peak-pressure level and B-duration from data recorded during firing of at least three single fired rounds. If the extreme spread of peak pressure level exceeds 3 dB, then additional rounds will he fired until the number of rounds equals or exceeds the extreme spread in dB. Use the mean peak pressure and B duration.

d. Reference Transducer.

If required, a transducer shall be placed 200 cm (79 in.) to the side of the major noise source of the weapon (e.g., perpendicular to the muzzle for closed breech systems and perpendicular to the rear for rocket launchers), with the weapon and the sensor 160 cm (63 in.) above the ground.

4.2.2 Equal Pressure Contours (140-dB Noise-Contour).

Where the impulse noise level exceeds 140 dB, the distances and directions from the noise source at which the noise level is equal to 140 dB shall be determined. Measurements are to be made at positions around the major noise source at angular increments not greater than 45 º. Where the 140-dB contour is too far from the source to make its direct measurement practical, its location may be extrapolated from measurements made at a distance producing a level not greater than 150 dB and assuming spherical divergence decay rate (6 dB per doubling of distance).

4.2.3 Materiel Other Than Weapons and Explosive Ordnance.

Items such as machinery (drop hammers, jackhammers, etc.) and impact tools that produce impulse noises are tested not only against impulse-noise criteria, but also against steady-state criteria when appropriate. For impulse noise tests, a minimum of five separate impulses is required to establish the arithmetic means of peak-pressure levels and B-duration as described in paragraph 1.2.c.

a. Stationary Machinery (e.g., drop hammers). Since these test items are not portable, they may be tested within an enclosure, the most suitable of which is the room or area of intended use.

b. Portable Machinery (e.g., pneumatic hammers). Conduct these tests in an open area free of all reflecting surfaces and where the ambient sound-pressure level is at least 25 dB below the values expected during the tests.

c. Operate the equipment using the operation and material causing the highest noise level and for as many operations as necessary to determine peak-pressure level, B-duration, and the 140-dB noise contour curve.

d. If the machinery requires other equipment in support of its operation (such as generators or air compressors), test the supporting equipment also for its steady-state noise level as indicated in paragraph 4.1.1.a.

5. DATA REQUIRED.

5.1 Steady-State Noise.

a. Test item nomenclature and identification data.

b. Test item condition (e.g., hatch position, with or without muffler, percent load, speed, etc.).

c. Test site (surface, terrain, etc.).

d. Type of test (stationary, highway, drive-by, etc.).

e. Meteorological data (temperature, humidity, barometric pressure, sky cover, wind direction, and velocity).

f. Nomenclature, model and serial numbers, and manufacturer of all instruments used.

g. Name of test conductor and equipment operator.

h. Microphone locations.

i. Sound levels in dBA, and in each octave band.

j. Noise-contour data (distances and directions from the equipment at which the specified noise limit is measured).

5.2 Impulse Noise.

a. Test item nomenclature and identification data.

b. Type of ammunition or explosive charge.

c. Test item condition (type mount, hatch-position mounting method, etc.).

d. Components and on-board equipment included.

e. Meteorological data (temperature, humidity, barometric pressure, sky cover, wind direction and velocity).

f. Nomenclature, model and serial numbers, and manufacturer of all instruments used.

g. Names of test conductor and equipment operator.

h. Microphone locations.

i. Peak-pressure level, A-duration, and B-duration measurements of impulse noise for each microphone location.

j. Noise-contour data (distance and directions from the test item at which 140-dB peak is recorded).

6. PRESENTATION OF DATA.

6.1 Steady-State Noise.

a. Tabulate all direct sound level meter measurement data using a data collection sheet.

b. When data are recorded, analyze the data in the laboratory for each specified requirement. If a requirement is not specified:

(1) Analyze the data for dBA, and octave-band sound levels in each octave band.

(2) Extract a portion of each test segment and perform a frequency analysis.

c. Present data taken for 85-dBA contour curves as shown in Figure 4.

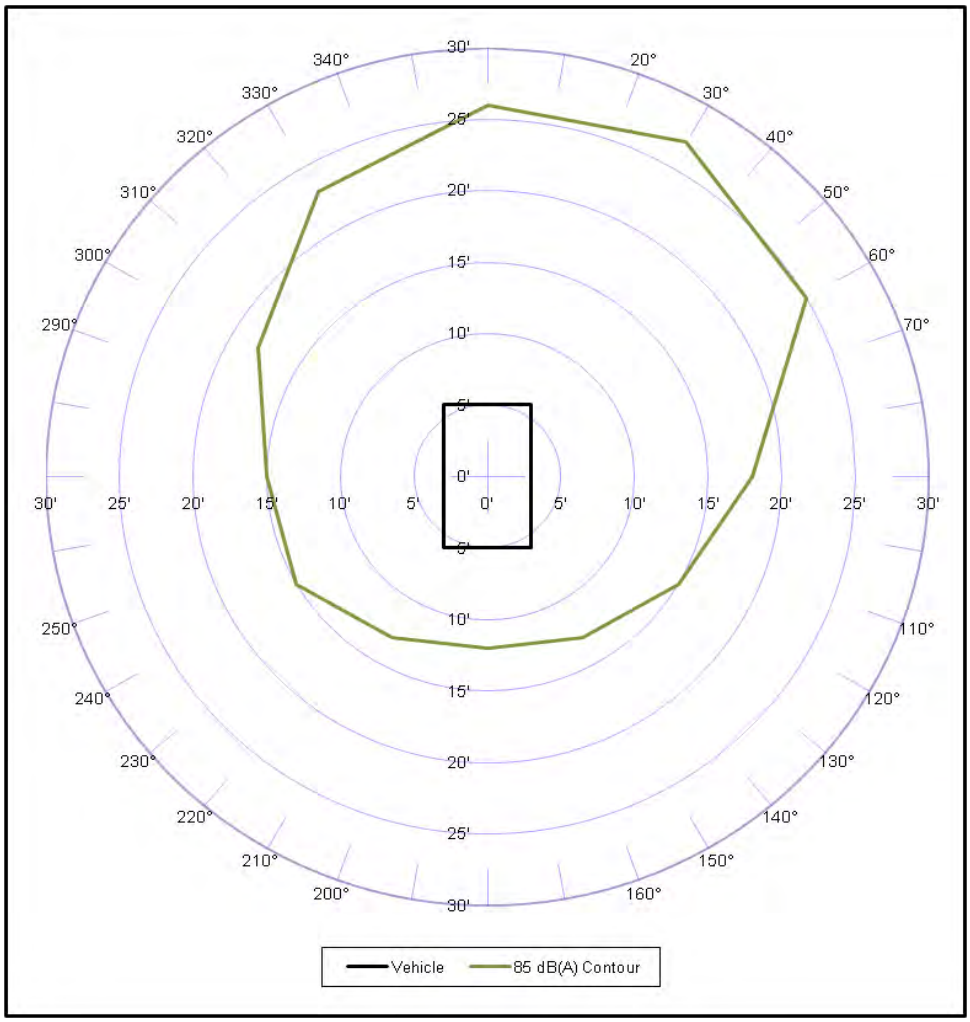

Figure 4. Typical 85 dBA noise contour curve for a military vehicle.

d. When required, compute the equivalent continuous noise level (Leq) as described in MIL-HDBK-1908B.

e. Assess the noise conditions referring to the steady-state noise level criteria in MIL-STD-1474D for the following, as applicable:

(1) Minimum distance personnel may approach without hearing protection.

(2) Type of hearing protection required.

(3) Type of communication possible.

(4) Distance of probable communication.

(5) Speech intelligibility.

(6) Maximum detectable distance.

(7) Primary sources of noise (i.e., exhaust, tracks, etc.).

6.2 Impulse Noise.

a. Analyze recorded data to determine peak-pressure level, A-duration, and B-duration. When speed-reduction techniques with direct-readout devices are used, the frequency-response characteristics of the devices must be at least proportionally equivalent to the characteristics of the recording device.

b. For systems that produce repetitive impulse, determine the number of impulses produced within the first 200 ms. This number of impulses is multiplied by the average B-duration of single impulses to determine an effective B-duration, which is used to establish the maximum allowable peak-pressure level for the repetitive system.

c. Tabulate the data taken to determine safety conditions for personnel as shown in Figure 5. When making comparison noise tests between two types of weapons or ammunition, or determining whether a simulator is loud enough to represent the actual device, only peak pressure levels are required and reported by round number.

d. Present data taken for 140-dB contour curves in a polar plot.

e. Compare the impulse-noise data with the limits for peak pressure level and B-duration specified in MIL-STD-1474D with special requirements established for the system under test.

Impulse-Noise Levels 20-mm Gun XM236

Crew Position No. 1				Crew Position No. 2			
Round	Peak Pressure Level (db)	"A" Duration* (ms)	"B" Duration* (ms)	Round	Peak Pressure Level (db)	"A" Duration (ms)	"B" Duration (ms)
1	152	0.7	111	1	146	1.0	141
2	153	0.8	106	2	145	1.2	137
3	151	0.9	101	3	146	0.9	135
4	152	0.7	107	4	145	1.1	131

Crew Position No. 3				Crew Position No. 4			
Round	Peak Pressure Level (db)	"A" Duration (ms)	"B" Duration (ms)	Round	Peak Pressure Level (db)	"A" Duration (ms)	"B" Duration (ms)
1	149	1.2	150	1	136	3.6	129
2	148	1.4	145	2	136	3.2	135
3	150	1.6	155	3	134	3.0	120
4	149	1.2	160	4	136	3.8	132

*"A" and "B" pulse duration as explained in MIL-STD-1474D.

NOTES: Driver's and commander's hatches were in the umbrella position – all other hatches were closed.
For explosive-ordnance test reporting (Paragraph 5.2), substitute microphone position for crew position.

Figure 5. Typical impulse-noise presentation.

f. Evaluate the noise condition for the following, as applicable:

(1) Minimum distance personnel may approach the area without hearing protection.

(2) Type of hearing protection required.

(3) Maximum of detectable distance.

APPENDIX A. CHARACTERISTICS OF NOISE.

A.1. General.

a. Sound. Sound is the sensation produced through the ear resulting from rapid fluctuations in atmospheric pressure. These fluctuations are expressed in decibels using 0.0002 microbar (which is the same as 0.0002 dynes/cm^2) as the reference pressure (often abbreviated to re 0.0002 bar). This reference is the smallest change in pressure at 1000 Hz that young men with good hearing can detect. The relative amplitude of these pressure fluctuations is termed the sound pressure level (SPL), and its value is given by:

$$\text{SPL (in db)} = 20 \log \frac{P_1}{P_o},$$

where P_1 is the overpressure and Po is the reference overpressure of 0.0002 microbar. For steady state noises, P_1 is the root mean square (rms) over pressure value, whereas for impulse noises, it is the instantaneous peak overpressure value. The relationship between overpressure expressed in psi and decibels is shown in Figure A-1 (one microbar = 1.450 x 10-5 psi.). Sound may be produced by a vibrating object that regularly compresses the air near its surface causing a wave to propagate from the object, or by pulses in the air generated by a shock wave and its reflections. For a simple, pure tone (i.e., a sine wave) the number of times per second the pressure changes through a complete cycle is the frequency of the sound. The audible frequency range for men with acute hearing is about 20 to 20,000 Hz. Normal speech involves the frequencies from about l00 to 7000 Hz, with the most important frequency centered about 1200 Hz.

b. Noise. Noise is unwanted sound. Noises may be divided in two ways:

(1) Steady state (or continuous), such as that produced by a tank or jet engine.

(2) Impulse (or impact or transient), such as that produced by gunfire.

A.2. Steady State Noises.

Steady state noises are continuous noises that maintain essentially the same amplitude and spectral distribution over a period of time. There are two principal types of steady state noises:

a. Steady state wide band noise which covers a wide range of frequencies (examples - noises from tanks, reciprocating engines, and ambient noise).

b. Steady state narrow band noise covering noises that range from pure tones to those that are concentrated in a frequency band of less than one-third octave (examples - noises produced by turbines, transformers, and sirens operating under constant conditions). Steady state noise levels are given as rms values expressed in decibels. Oscillograph traces of steady state noises are shown in Figure A-2.

APPENDIX A. CHARACTERISTICS OF NOISE.

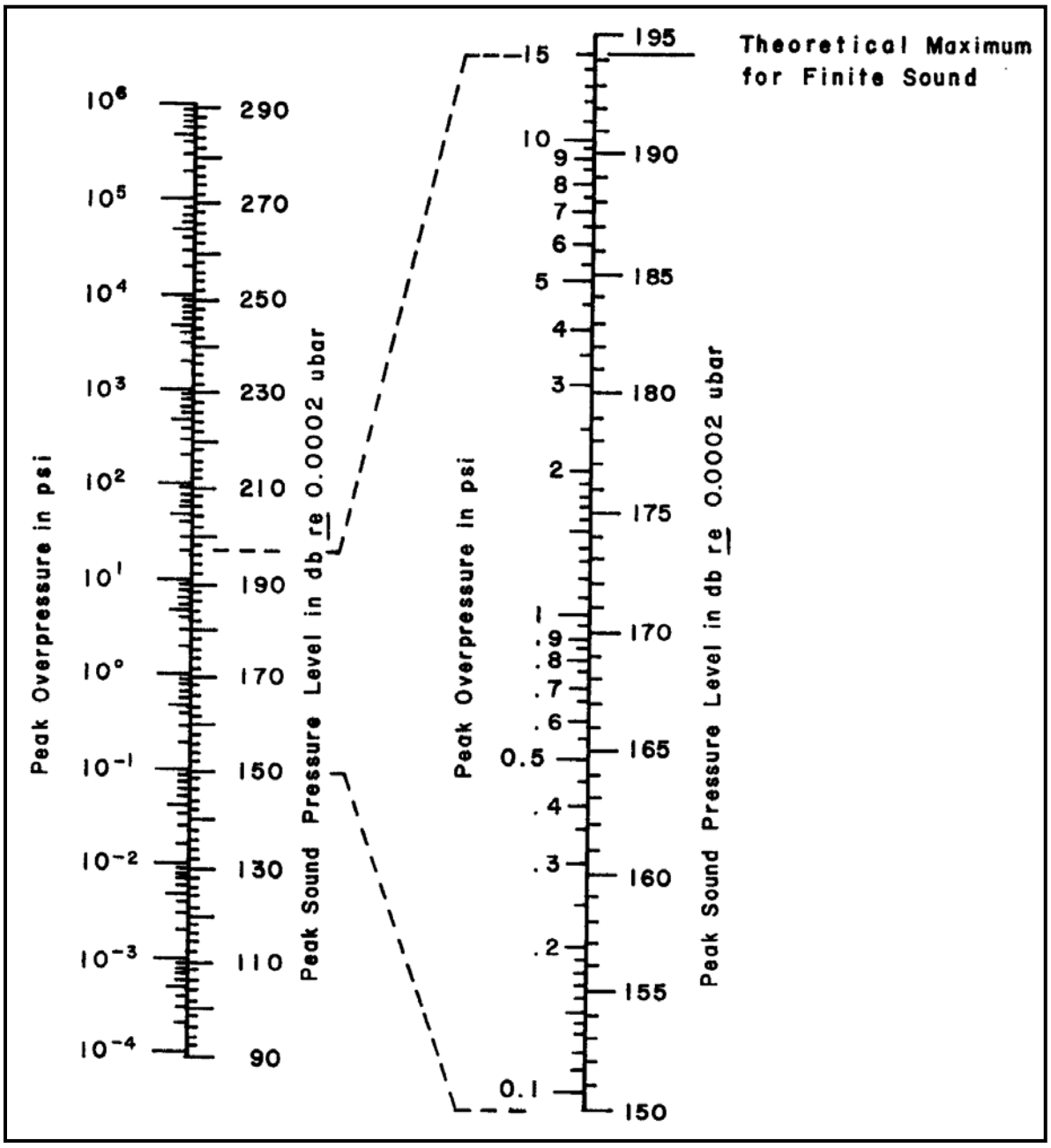

Figure A-1. Relationship of overpressure measurements to noise levels
(to convert from psi to kPa multiply by 6.89).

APPENDIX A. CHARACTERISTICS OF NOISE.

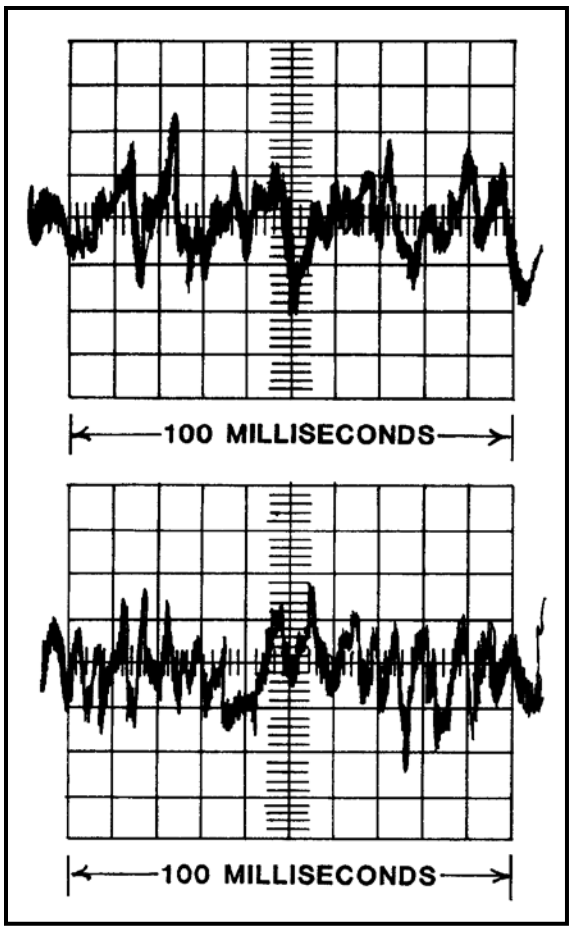

Figure A-2. Typical steady state noise oscilloscope traces.

A.3. Impulse Noises and Blast Waves.

An idealized impulse noise produces the same physical phenomenon as a blast wave. A shock front is created, which is characterized by a discontinuity in pressure. The pressure rise from ambient to peak occurs in less than a microsecond. In practice, there may be precursors in the form of advance elements of the gun-firing process which arrive before the main muzzle blast. Reverberations and reflections also increase the complexity of the wave form creating a number of nodes. The duration of an impulse noise is generally in the millisecond range for large weapons and in microseconds for small arms. Impulse noises that are repeated rapidly, such as machinegun fire, are called repeated impulse noises. In some cases, such as with gun noises heard from within a closed tank, the impulse has no apparent shock front. Peak sound pressure levels in decibels can be directly converted to blast overpressures in psi by the use of Figure A-1. Blast overpressure and impulse noises are discussed in greater detail in ITOP 04-2-822.

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APPENDIX B. ABBREVIATIONS.

ANSI	American National Standards Institute
AR	Army Regulation
DA PAM	Department of the Army Pamphlet
dB	decibel
DC	direct current
FM	frequency modulation
Hz	hertz
IRIG	International Range Instrumentation Group
ITOP	International Test Operations Procedure
kHz	kilohertz
kmh	kilometers per hour
kPa	kilopascal
Lavg	average level
MIL-HDBK	military handbook
MIL-STD	military standard
mph	miles per hour
ms	millisecond
psi	pounds per square inch
SAE	Society of Automotive Engineers
SOP	Standing Operating Procedure
TB MED	Technical Bulletin Medical
TOP	Test Operations Procedure

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APPENDIX C. DATA COLLECTION SHEET.

ACOUSTICAL TEST DATA

TIME: 1400	DATE: 21 JULY 2010				
TEST ITEM: TRUCK: CARGO, 1¼ TON, 6×6, M561				TEST CONDUCTED BY: WM. H. DIEGEL	TEST ITEM OPERATOR: TONY MILLER
REG./MODEL NO: 03A 476 70	SERIAL NO: 7252 511C	ODOMETER: 13,500	HOUR METER	TEST ITEM CONDITION: STANDARD CANVAS TOP - DOORS OPEN	
TEMPERATURE: 24.7°C	HUMIDITY: 63%	TEST SITE: PERRYMAN		SURFACE: PAVED	TERRAIN: LEVEL
BAROMETRIC PRESSURE: 1012.2	SKY COVER: SCATTERED	STATIONARY OPERATION: ☐	HIWAY DRIVING: ☒	DRIVE-BY: ☐	
WIND DIRECTION: S.S.W	WIND VELOCITY: 4.5 - 5.0 m/s	MICROPHONE: GR-1551-P1	SOUND LEVEL METER: GR-1551-C	OCTAVE ANALYZER: GR-1558AP	
INTERIOR: ☒	EXTERIOR: ☐	MICROPHONE LOCATION: AS DESCRIBED BELOW		TAPE RECORDER: —	TAPE NO.: —

GEAR	RPM	APPROX SPEED	dbA	dbB	dbC	ALL PASS	31.5	63	125	250	500	1,000	2,000	4,000	8,000	REMARKS
								DRIVER'S EAR POSITION								
1	1900	4	91	94	95	96		87	89	91	90	86	82	76	69	
2	1900	9	92	95	96	97		87	89	91	89	86	82	76	69	
3	1900	21	92	95	97	97		88	89	91	90	87	82	75	69	
4	1900	38	93	96	99	100		90	91	95	90	88	82	76	70	
								PASSENGER'S EAR POSITION								
1	1900	4	89	92	94	95		86	88	92	88	84	81	75	68	
2	1900	9	90	92	94	95		86	87	92	87	85	81	75	68	
3	1900	21	90	93	95	97		86	88	93	90	86	82	75	68	
4	1900	38	92	95	97	98		87	90	95	90	87	82	77	69	
			85					106	96	89	83	80	79	79	81	MAXIMUM ALLOWABLE LIMITS FOR UNPROTECTED HEARING (MIL-STD-1474 CATEGORY 'D')

Figure C-1. Data collection sheet.

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APPENDIX D. REFERENCES.

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2. MIL-HDBK-1908B, Definitions of Human Factors Terms, 16 August 1999.

3. MIL-STD-1474D, Design Criteria Standard, Noise Limits, 12 February 1997.

4. ANSI S1.13, Measurement of Sound Pressure Levels in Air, 2010.

5. ANSI Sl.4, Sound Level Meters, 2006.

6. ANSI S1.11, Octave-Band and Fractional-Octave-Band Analog and Digital Filters, 2009.

7. ANSI S6.1, Qualifying a Sound Data Acquisition System, 1973.

8. AR 40-5, Preventive Medicine, 22 July 2005.

9. TB MED 501, Occupational and Environmental Health: Hearing Conservation), 15 March 1980.

10. DA PAM 40-501, Hearing Conservation Program, 14 January 2006.

11. SAE J366, Exterior Sound Level for Heavy Trucks and Buses, 1 February 1987.

12. SAE J88, Sound Measurement - Off-Road Work Machines – Exterior, 1 February 2006.

13. SAE J34, Exterior Sound Level Measurement Procedure for Pleasure Motorboats, 1 July 2005.

14. TOP 01-2-610, Human Factors Engineering Part 1: Test Procedures, 15 May 1990.

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Forward comments, recommended changes, or any pertinent data which may be of use in improving this publication to the following address: Range Infrastructure Division (CSTE-TM), U.S. Army Test and Evaluation Command, 2202 Aberdeen Boulevard, Aberdeen Proving Ground, MD 21005-5001. Technical information may be obtained from the preparing activity: Soldier Systems Division (TEDT-AT-WFS), U.S. Army Aberdeen Test Center. Additional copies can be requested through the following website: http://itops.dtc.army.mil/RequestForDocuments.aspx, or through the Defense Technical Information Center, 8725 John J. Kingman Rd., STE 0944, Fort Belvoir, VA 22060-6218. This document is identified by the accession number (AD No.) printed on the first page.